UTAH OFFICE OF
ENERGY DEVELOPMENT

Matter, Heat, and Insulation

Grade/Subject: 6th Science

Strand/Standard 6.2.4 Design an object, tool, or process that minimizes or maximizes heat energy transfer. Identify criteria and constraints, develop a prototype for iterative testing, analyze data from testing, and propose modifications for optimizing the **design solution**. Emphasize demonstrating how the structure of different materials allows them to function as either conductors or insulators. (PS3.A, PS3.B, ETS1.A, ETS1.B, ETS1.C)

Lesson Performance Expectations:
Students will use the engineering process to develop an insulated container to minimize the loss of heat energy.

Materials: A group of 4 needs.

- Hot water and source for it
- 1 Film Canister or 1 plastic cup (1 film canister per group of students or one cup)
- Thermometer (1 per group)
- Bubble-wrap, cotton, bigger cups, and other items to be used for insulation
- Timers (1 per group)
- Thermos to show
- Laptops or digital devices for research

Time: Two 45 minute periods. The teacher could run only the first one and have the students design a solution without making/testing it in one day.

Teacher Background Information:

- Oil is found in many parts of Utah. In locations like the Uinta Basin (Duchesne, Uintah, Grand, and Carbon counties, petroleum is not the liquid oily substance that we typically think of. Instead of being a black liquid, it is often a waxy substance, called “waxy crude,” that hardens when it loses heat and its temperature decreases. This oil is hot enough to stay a liquid when it is underground. As soon as it reaches the surface, it begins to cool. If it is not kept sufficiently warm using some kind of insulator, it will harden like wax.

- Waxy crude is a unique resource in Utah’s fossil fuel portfolio. However, transporting waxy crude before it hardens is a challenge. Engineers have found that the most cost-effective way to keep the crude below its solidifying point while it transports to the refineries is through insulated containers. Insulation will be used until a more efficient method for keeping the oil liquid is found.

- A basic understanding of heat transfer is needed. What is heat transfer? Why are we concerned about heat energy transfer or heat loss/gain?

- Heat is a form of energy associated with the movement of atoms and molecules in any material. The higher the temperature of something, the faster the atoms move, and the more energy is present. Atoms move more slowly (less freely) when the matter is in a solid-state. When the temperature rises, the atoms move more freely; eventually, the atoms move fast enough to change the state from a solid to a liquid (melting point) or from a liquid to a gas (boiling point). Check out this free simulation to see how different atoms respond to different pressures and temperatures. The opposite is also true. When heat is removed (when an object cools), the movement of the atoms slows down; eventually, the gas becomes a liquid, which will then become a solid (freezing point) with enough heat loss. In addition to heat, pressure also has an impact on phase changes. When pressure increases, it compresses the molecules into a tighter space, keeping them from expanding. When this happens to a gas, that gas becomes a liquid; when it happens to a liquid, the substance becomes a solid.

Student Background Knowledge:
Students need to be familiar with heat energy, heat transfer (definition), and the engineering process (very basic understanding).

Teacher Step by Step: A 3-d lesson should insist students do the thinking. Provide time and space for the students to experience the phenomenon and ask questions. The student sheet below provides guidance but is only an example of how students might respond.

1. **Introduce *Phenomenon:*** Show the picture of waxy crude oil, giving them a little background of its changes in forms. Ask the students to write down three questions they have. Discuss with the students the challenges of waxy crude oil. Use the different online resources found here to discuss why the oil industry needs to find a way to keep the oil warm, so it does not cool into a waxy form. (Alternative phenomenon: show this video Energy Efficiency)
2.  
3. Show a thermos or a picture of one. Heat energy can be gained or lost due to the cooling or heating effects of the environment. Ask students why they think this thermos can keep something hot on a cold day and have them write ideas down.
4. Students will investigate with hot water. The students will be trying to keep the hot water as warm as possible for the designated time. For the investigation, students will use the film canister or cup. They will use other insulating materials to help the container be as effective as possible.
5. Students then make modifications to the container for a second test.
6. Students will use the student sheet to record observed temperatures under the evidence portion and give reasoning. They will then formulate a claim on how these experiments work and an explanation.
7. Answers for questions 1-4 on the student worksheet Why does the waxy crude oil cool off when brought out of the ground? *The temperature will be an average of 110 - 120 degrees, so daily temperatures are lower. It can be*

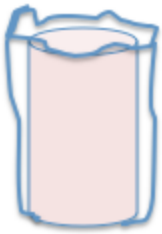
warmer if there is geothermal energy in the area. What problems would that make for transportation of the waxy crude oil? *The oil will turn into a solid. As the oil is transported through the pipes, the oil solidifies and will not flow. This will stop the flow of the oil. It is also transported in tanker cars.* Why would a cross-section of a pipe carrying waxy crude oil look like this? How is waxy crude oil usually transported? *Pipelines and tanker cars and big ships.* What do we use crude oil for? *We use the oil to make more pure forms that are used for energy.*

Assessment of Student Learning. Write a claim statement providing evidence (data) to support the claim. You must include reasoning and describe why the structure of your design worked as an insulator.

Standardized Test Preparation:

Matter, Heat, and Insulation

Insulated Cups



Plastic wrap

Wool sock

Students designed two insulation systems for plastic cups of hot wax. One was wrapped in plastic, and the other was a wool sock. Their test results are below:

Time	Plastic Wrap Temperature (F°)	Wool Sock Temperature (F°)
0 minutes	150°	150°
10 minutes	120°	135°
20 minutes	100°	125°

1. Which insulation worked best to insulate the wax?
    a. The plastic wrap
    b. The wool sock*
    c. They were too close to say.
2. How was the wool sock different from the plastic wrap? Choose all that apply.
    a. It trapped air around the cup.*
    b. It was thicker.*
    c. It was made from matter.
    d. It was wrapped around the cup.

3. What role did heat transfer play in the design of the insulation?
    a. Heat transfer was being prevented.*
    b. Heat transfer was being encouraged.
    c. Heat transfer was at the beginning of the experiment.
    d. Heat transfer was at the end of the experiment.

4. Based on these results, what other types of insulation would be effective? Choose all that apply.
    a. A layer of bubble wrap.*
    b. A layer of aluminum foil.
    c. Cotton balls taped around the cup.*
    d. Two layers of wool socks.*

Extension of lesson: Try the same lesson but with cold liquids to see if their design will also keep the temperature constant. Research how Utah's waxy crude is currently shipped and how it is kept in a liquid state. Present findings to the class. Research concepts like cavitation and cracking and how they apply to the transportation of waxy crude. What could you study in college to help fix problems like this?

Career Connection: Insulation/Weatherization Specialists, HVAC Technicians, Energy/Mechanical Engineers. Potentially invite an HVAC tech for the school to talk about energy transfer and managing insulation for large buildings.

Matter, Heat and Insulation Secondary

Name_____

Phenomenon #1: Look at the picture of waxy crude oil. List 3 questions you have about it.

1.

2.

3.

Phenomenon #2: List 3 structural designs that you think the hot beverage thermos has that enables it to keep hot chocolate warm for a long time.

1.

2.

3.

Materials:

Using these ideas and materials, you will design a container to keep your water hot. You will need one film canister/cup, hot water, bubble wrap, cotton balls, other insulating materials, a roll of tape per group, and a thermometer.

Initial Container Design: Draw the container below as you will use it for your first experiment. The hot water, entire container, and insulation materials must be included and labeled.

Evidence Section

Data Table (your evidence from the experiment): Measure and record the water temperature in the container every 5 minutes. While waiting, work through the scenarios that follow this data table.

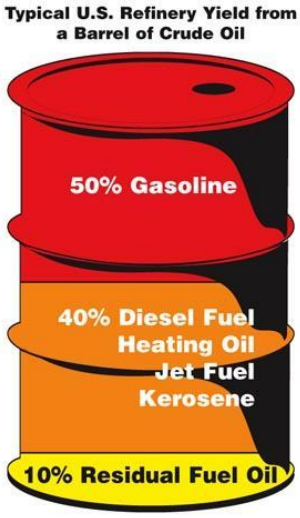
Container #	Temp Start	Temp 5 min.	Temp 10 min.	Temp 15 min.	Temp 20 min.	Temp 25 min.
Trial #1						

Answer research questions as a group while you wait.

1. Why does the waxy crude oil cool off when it is brought out of the ground?

2. What problems would that make for transportation of the waxy crude oil?

3. Using this diagram, write several summary statements about what crude oil is used to make.



4. Why would a cross-section of a pipe carrying waxy crude oil look like this?

5. How can what you learn from your design help engineer an oil pipeline that enables the better flow of waxy crude oil?

Redesign your second container with its insulation and sketch it here. Please label all the changes that you are going to make. Write a statement describing how the structure of different materials allows them to function as insulators.

Container #	Temp Start	Temp 5 min.	Temp 10 min.	Temp 15 min.	Temp 20 min.	Temp 25 min.
Trial #2						

Reasoning

1. Which container maintained the original or starting temperature for the longest period? Why do you think this was the case?

2. Which container maintained the original or starting temperature for the shortest period? Why do you think this was the case?

Explanation: Write a claim statement providing evidence (data) to support the claim. You must include reasoning and describe why the structure of your insulating materials functioned as an insulator. Include the words “heat transfer, heat energy, temperature, or heat loss” in your explanation.